Growth of AlGaN/GaN heterostructures at various NH_3 flows and reactor pressures and their 2DEG transport properties

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The effects of NH_3 flow rate and reactor pressure on Al incorporation in AlGaN by metalorganic chemical vapor deposition (MOCVD) and the electrical interface properties of AlGaN/GaN heterostructures were studied. It was found that alloy compositional grading became larger at AlGaN/GaN heterointerfaces at higher reactor pressures, higher Al composition, and low NH_3 flow rate. This compositional grading over the heterostructure interface lowered sheet carrier concentration and electron mobility as well. We obtained an AlGaN/GaN heterostructure with sheet carrier density of ~$2x10^{13}$ cm^{-2} and mobility of 1200 and 7000 cm^2/Vs at 300K and 100K, respectively.

The 30 nm AlGaN layers were grown at 1060 ^oC on 2 μm-thick undoped GaN layers (~ 500 cm^2/Vs, mid $10^{16}cm^{-3}$) on c-plane sapphire substrates by MOCVD in a vertical reactor. NH_3 flow rate, reactor pressure, and Al/(Ga+Al) input ratio were varied from 15 to 25 l/min, from 100 to 300 Torr, and from 0.15 to 0.40, respectively. Al composition was measured by high-resolution x-ray diffraction and secondary ion mass spectrometry (SIMS). SIMS and Auger electron spectroscopy (AES) depth profiling were used to determine the compositional profile at the AlGaN/GaN interfaces. The mobility and the sheet carrier concentration were measured by Van der Pauw method at liquid nitrogen temperature.

It was found that the Al content in AlGaN films increased with gas-phase input ratios, Al/(Ga+Al), as shown in Fig. 1. Furthermore, Al was incorporated more efficiently into AlGaN as NH_3 flow rates decreased from 25 to 15 l/min and the total pressured increased from 100 to 300 Torr. It is believed that the equilibrium vapor pressure of Al over the growth surface is significantly lower than that of Ga, leading to the preferential Al incorporation into the AlGaN films. The Al concentration profiles in AlGaN films (reactor pressure of 300 Torr), as measured by SIMS, are shown in Fig. 2. As the Al content in the films increased, the Al concentration profile near the interface became more and more graded. Figure 3 shows the changes in Al incorporation profiles at two different reactor pressures, 100 and 300 Torr. In both cases the NH_3 flow rates were kept constant at 25 l/min. From these results, it can be concluded that a growth condition of higher NH_3 flow rate, lower reactor pressure and lower gas-phase Al input ratio is preferable to obtain better AlGaN/GaN interfaces. The interfacial abruptness degraded when the Al content exceeded 0.32. The compositional grading at the AlGaN/GaN heterointerface might be related with the structural relaxation due to misfit strain as well as the gas-phase parasitic reaction between NH_3 and TEAl at high reactor pressure and high Al mole fraction in the gas phase.

The electrical properties of the AlGaN/GaN heterointerfaces were characterized by measuring the mobility of the 2-dimensional electron gas (2DEG) and the sheet carrier concentration. At the reactor pressure of 300 Torr, the interface became worse with when Al content increased from 0.32 to 0.50, as shown in Fig. 4. The mobility was reduced drastically at higher Al content. The sheet carrier concentration also reduced from $2x10^{13}$ to $8.5x10^{12}/cm^2$, presumably due to the high density of trap associated with structural relaxation. On the other hand, in the films with low Al content ranging from 0.13 to 0.30 (grown at 100 Torr), the sheet carrier concentration increased from $1.1x10^{13}$ to $2.1x10^{13}/cm^2$, as shown in Fig. 5. In these low Al content AlGaN films, structural relaxation might not severe. Instead, polarization might increase with Al content and the polarization-induced electric fields might lead to a significant increase in sheet carrier concentration. Sheet carrier concentration increased from $1.5x10^{13}$ to $2.0x10^{13}/cm^2$ in Fig. 6 when the AlGaN thickness increased from 15 to 35 nm and the sheet carrier concentration became saturated for thickness above 30 nm at Al content of 0.32.

In conclusion, Al incorporation behavior was investigated at various growth pressures and NH_3 flow rates. It was found that Al was incorporated more efficiently in the AlGaN films. Severe compositional grading in AlGaN/GaN heterointerfaces was observed at higher reactor pressure and lower NH_3 flow rate. The $Al_{0.3}Ga_{0.7}N$/GaN heterostructure with sheet carrier concentration of $2.0x10^{13}$ cm^{-2} could be obtained. The electron mobilites of the heterostructure were 7,000 and 1,200 cm^2/Vs at 100 K and 300 K, respectively.

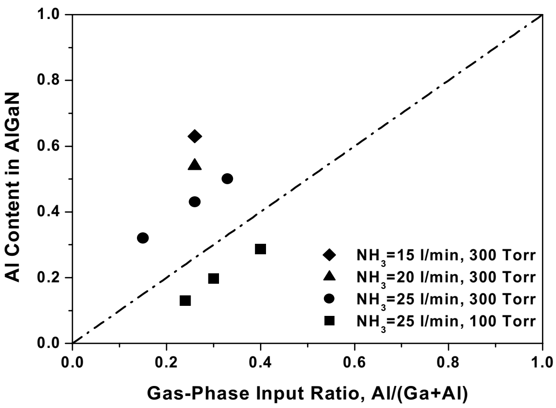

Fig.1 Changes in Al content in AlGaN films at various input ratios.

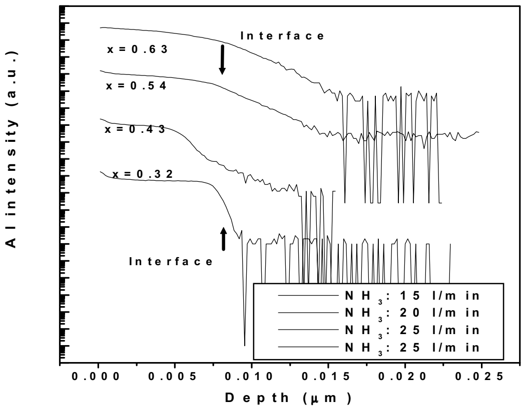

Fig. 2 SIMS depth profile for AlGaN/GaN films grown at 300 Torr. NH_3 flow rates were varied from 15 to 25 l/min

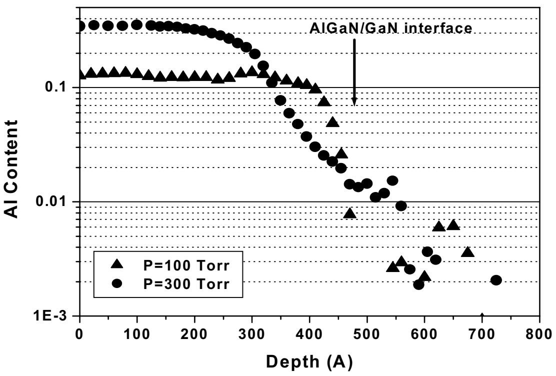

Fig. 3. AES depth profile for samples growth at 100 Torr and 300 Torr. NH_3 flow rate and gas-phase input ratio are 25 l/min and 0.26, respectively.

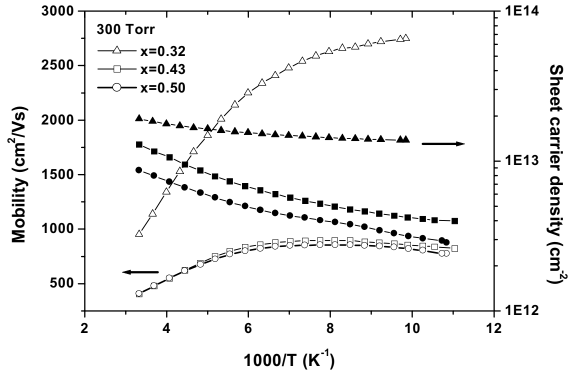

Fig.4. Electron mobility and sheet carrier concentration of AlGaN/GaN heterostructures, x=0.32~0.50 grown at 300 Torr.

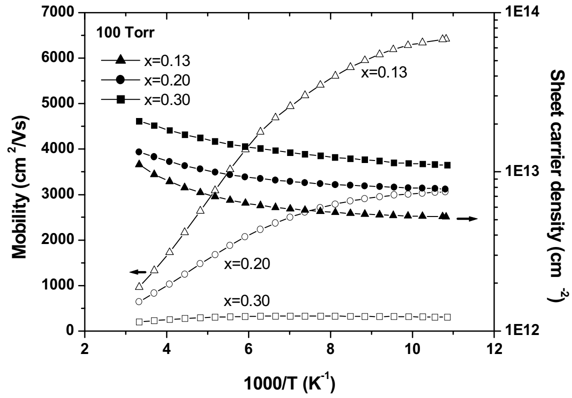

Fig. 5. Electron mobility and sheet carrier concentration of AlGaN/GaN heterostructures grown at 100 Torr.

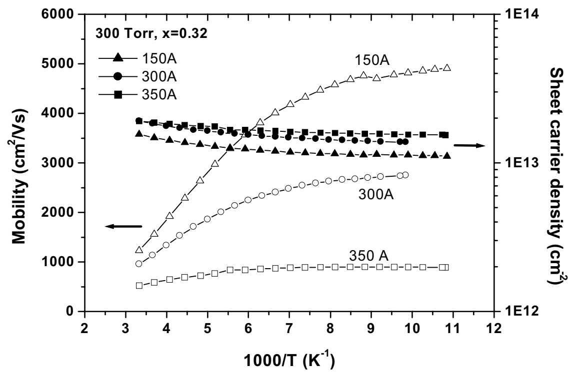

Fig. 6. Mobility and sheet carrier concentration of AlGaN/GaN heterostructures grown at 300 Torr with different thicknesses, 150A~350Å, x=0.32.